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FOR

# MOTOR WITH RAISED ROTOR

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# MOTOR WITH RAISED ROTOR

## Field of the Invention

The present invention relates to motors, and more particularly, to a support of a rotor within a motor having a sleeve bearing.

## Background of the Invention

Motors are employed in a multitude of situations requiring various orientations. Among other uses, motors can be used in fans or drive a toy car. A fan driven by a brushless DC motor, for example, has a movable portion (i.e., a rotor) rotatably coupled with a stationary portion (i.e., the stator). The rotor typically has an impeller (or propeller) coupled to a shaft that is rotatably secured to a bearing within the stator. To rotate the rotor, the stator produces a rotating magnetic field that, when interacting with a magnet in the rotor, causes the rotor to rotate about an axis defined by the shaft.

Motors can use different types of bearings to rotatably secure the shaft to the stator. For example, some motors use a sleeve bearing, which generally is a highly lubricated, porous sleeve that maintains the radial position of the rotor within the motor. Lubrication of the porous walls of the sleeve bearing should minimize friction that arises between the shaft and sleeve walls, thus permitting the rotor to more freely rotate.

The hub of the rotor (in conjunction with other components) commonly maintains the axial position of the rotor. More particularly, some fans have a thrust washer captured between the rotor hub and sleeve bearing. One function of the thrust washer is to act as a loose lid on the sleeve bearing, thus retaining (to some extent) lubricant within the porous walls of the sleeve bearing. During operation, the hub rubs against the thrust washer that in turn rubs against the top of the sleeve

bearing. If this friction is not minimized, fan efficiency is reduced, which leads to the need for larger fan motors and additional power consumption. Both consequences are adverse to the use of fans in cooling increasingly smaller and hotter operating electrical components and equipment.

## Summary of the Invention

In accordance with one aspect of the invention, a motor has a stator, a rotor having a shaft, and a sleeve bearing in contact with the rotor shaft. The sleeve bearing also is fixedly secured to the stator. Additionally, the motor also has a movable support member axially supporting the shaft. The movable support member illustratively is movable relative to the shaft.

In certain embodiments, the motor has a housing encasing the stator to form a recess for supporting the moveable support member. The moveable support member may be a spherical member, and, in some cases, may be a ball bearing. The recess may have a depth less than a radius of the spherical member.

In other embodiments, the motor may contain a retaining washer about the shaft. The retaining washer may be contained between the lower end of the shaft and the sleeve bearing.

In additional embodiments, the motor may contain a rotor hub coupled to the shaft and spaced from the sleeve bearing.

In further embodiments, the rotor may include a rotor magnet oriented with the stator to bias the rotor toward the moveable support member.

In other embodiments, the moveable support member may contact the shaft when the motor is right side up and when the motor is upside down.

In accordance with another aspect of the invention, a motor has a stator with a sleeve bearing, a rotor having a hub mounted to a shaft that is rotatably coupled with the sleeve bearing, and a movable support member supporting the weight of the rotor. The shaft has a coupled retaining member.

In certain embodiments, the motor also may have a housing about the stator. In some embodiments, the retaining member may be a washer secured to the shaft. In additional embodiments, the rotor may include blades for moving air. In other embodiments, the rotor includes a rotor magnet that normally biases the rotor toward the support member.

The support member may have a number of shapes. For example, it may have a spherical shape. The motor may be any type of motor and thus, the stator may have DC commutation circuitry.

In accordance with a further aspect of the invention, a motor has a stator, a rotor having a shaft, and a sleeve bearing in contact with the rotor shaft. The sleeve bearing also is fixedly secured to the stator. Additionally, the motor also has a movable means for axially supporting the shaft. The movable support means illustratively is movable relative to the shaft.

In one embodiment, the moveable means for axially supporting may include a ball bearing. In another embodiment, the motor may include a housing encasing the stator with the housing forming a recess for supporting the moveable means. Additionally, the shaft may have an attached rotor hub spaced from the sleeve bearing. In certain embodiments, the rotor may include means for biasing the rotor toward the moveable means for axially supporting.

## Brief Description of the Drawings

The foregoing features of the invention will be more readily understood by reference to the following detailed description, taken with reference to the accompanying drawings, in which:

Figures 1a and 1b schematically show an illustrative motor implemented within a fan assembly that may incorporate various embodiments of the invention.

Figure 2 schematically shows a cross-sectional view of the fan shown in figure 1 implemented in accordance with illustrative embodiments of the invention.

Figure 3 schematically shows a blown-up cross-sectional view of the circled portion of the fan shown in figure 2.

## Detailed Description of Illustrative Embodiments

In illustrative embodiments of the invention, a motor has a support member (e.g., a movable ball bearing) that normally supports the weight of a rotor shaft. Such embodiments are particularly effective when incorporated into a motor that uses a sleeve bearing. Specifically, the support member may lift the rotor shaft a small amount to ensure that the rotor hub does not frictionally contact any components on the stator (e.g., the sleeve bearing). Consequently, the rotor has less frictional resistance as it rotates about its axis.

The motor may be implemented as a fan that cools heat generating components, such as hot water heaters or enclosed computer compartments. Certain aspects of such cooling thus can impose particular demands on fan motor reliability. For example, failure of the fan can cause catastrophic overheating of components (e.g., computer processors within a computer system). Moreover, because a fan may not be easily accessible, replacement or repair of the fan may be complicated and lead to extended downtime of electrical equipment. Fan operation is further complicated because of the variety of possible fan orientations and positions. Details of various embodiments of the invention are discussed below.

Fig. 1a shows a fan assembly **100** that may incorporate illustrative embodiments of the invention. The fan assembly **100** contains a housing **110** formed by a front cover **106** and a back cover **108**. The front cover forms an inlet duct **102** while the back cover forms an outlet duct **104**. The front and back covers **106** and **108** illustratively are removably snap fit together to form an interior that contains a

fan **120** (Fig. 1b). Accordingly, the interior components (discussed below) may be easily accessed. In alternative embodiments, however, the front and back covers **106** and **108** are fixedly secured together.

Figure 2 schematically shows a cross-sectional view of the fan assembly **100** shown in figure 1. The fan **120** includes, among other things, a brushless DC fan motor **210**. Specifically, the fan motor **210** has a rotational portion (i.e., a rotor **220)** that is rotatably coupled with a stationary portion (i.e., a stator **230)**. As noted above, the stator **230** illustratively has an electromagnet **231** that interacts with a permanent magnet **260** in the rotor to cause the rotor **220** to rotate. To that end, the stator **230** illustratively has conventional brushless DC commutation circuitry **40** (e.g., Hall sensors, switches, etc...) and DC motor components (poles, coils, etc . . .) commonly included in the stator **230** of a brushless DC motor.

As suggested above, the rotor **220** includes an annular permanent magnet **260** within a steel cup 38, and a plastic impeller **30** having fan blades extending from a plastic hub **227** mounted about the steel cup **38**. Of course, the impeller **30** also may be a propeller or other similar apparatus utilized in fans. A sleeve bearing **232** in the stator assembly **235** receives a central shaft **223**, which is secured to the hub **227**.

It should be noted that discussion of a brushless DC motor is exemplary and not intended to limit all embodiments of the invention. For example, some aspects of the invention could be applied to synchronous motors or DC motors with brushes. Accordingly, those in the art may apply principles of the invention to other types of motors. In a similar manner, discussion of a fan is exemplary and thus, not intended to limit all embodiments of the invention. Accordingly, the in the art may apply principles of the invention to motors implemented in other types of devices.

The sleeve bearing **232** illustratively is slip fit into a chamber **237** in the stator **230** in a conventional manner. An upper O-ring **252** and lower O-ring **254** secure the

sleeve bearing **232** within the stator chamber **237**. In illustrative embodiments, the sleeve bearing **232** is formed by means of conventional powdered metal manufacturing processes to form its cylindrical, porous surface. As known by those in the art, the porosity of the sleeve bearing enables its surface to receive and, to some extent, retain a lubricant, such as oil or petroleum derivative product. The lubricant reduces frictional resistance caused by the contact between the outer surface of the shaft and the inner surface of the sleeve bearing. Of course, to permit rotation, the inner diameter of the sleeve bearing **232** illustratively is larger than the outer diameter of the shaft **223**. For example, the sleeve bearing **232** may have an inner diameter that is about 0.004 to 0.010 inches larger than the outer diameter of the shaft **223**. These clearances should facilitate proper motor operation.

In addition, the center of gravity **238** of the rotor **220** that includes shaft **223** may be arranged to coincide with the upper opening **239** in the sleeve bearing **232** for shaft **223**. As a result, the life of sleeve bearing **232** may be extended. A center of gravity **238** above this point may lead to ovaling out of the upper opening **239**. A center of gravity **238** below this point may lead to chatter.

The shaft **223** also has upper and lower thrust washers **242** and **244** to at least partially retain lubricant within the sleeve bearing **232**. As discussed in greater detail below, the upper and lower thrust washers **242** and **244** do not entirely retain lubricant within the sleeve bearing **232**. Instead, they effectively act as unsealed lids to the sleeve bearing **232**, thus creating some resistance to migrating lubricant. Accordingly, the top thrust washer **242** may be nominally positioned to be substantially flush against the top of the sleeve bearing **232**. In a similar manner, the bottom thrust washer **244** also may be nominally positioned substantially flush against the bottom of the sleeve bearing **232**.

The thrust washers **242** and **244** are not fixedly secured to the shaft or sleeve bearing. Instead, the thrust washers **242** and **244** merely are slip fit around the outer surface of the shaft **223**. Accordingly, during operation, the thrust washers **242** and

**244** may rotate at a different rate than that of the shaft **223**. Among other things, this difference is based upon the amount of lubricant the thrust washers receive. Due to their relatively loose coupling about the shaft **223**, the thrust washers **242** and **244** may slide upwardly or downwardly during the lifetime of the motor **210**. The amount of this movement can be limited, however, by axially adjacent components, such as a rotor hub **227**.

The motor **210** also includes a retaining member **310** (Fig. 3) for ensuring that the rotor **220** remains appropriately axially positioned within the sleeve bearing **232**. Among other things, the retaining member **310** may be a washer that normally remains positioned within a closed, cylindrically shaped base portion **320** of the housing **110**. To minimize or eliminate frictional resistance, the retaining member **310** has a maximum transverse dimension that is less than the minimum inner dimension of the cylindrically shaped base portion **320** of the housing **110**.

Moreover, unlike the thrust washers **242** and **244**, the retaining member **310** may be secured to the shaft **223** a short distance from the bottom of the sleeve bearing **232**. In illustrative embodiments, that distance is slightly greater than the maximum thickness of the lower thrust washer **242**. Because it is not axially movable along the shaft **223**, the retaining member **310** should substantially maintain the axial position of the rotor **220** within the sleeve bearing **232**. Those skilled in the art can select the position of the retaining member **310** on the shaft **223** to optimize performance.

Alternative embodiments may not use a washer as the retaining member **310**. For example, the shaft **223** may have a transverse through-hole through which a pin is inserted. Accordingly, discussion of a washer is exemplary and not intended to limit the scope of various other embodiments of the invention.

In accordance with illustrative embodiments of the invention, the rotor **220** is slightly elevated to minimize friction between 1) the rotor hub **227** and the upper thrust washer **242** and 2) corresponding friction between the thrust washer **242** and

the sleeve bearing **232**. In other words, the lift should significantly reduce or eliminate the frictional contact (i.e., resistance) between these adjacent components. Minimizing (or eliminating) this friction should improve motor efficiency. To that end, a base interior surface **111** of the housing **110** has a recess **340** that contains a movable support member **330**, such as a single ball bearing. The support member **330** normally supports the entire weight of the rotor **220**.

It should be noted that discussion of the spherically shaped support member **330** is illustrative and not intended to limit various other embodiments of the invention. For example, in other embodiments, the movable member **330** may be disk shaped with rounded surfaces, or cylindrically shaped. Of course, the recess **340** should be shaped to at least in part retain the support member **330**. Moreover, the bottom **224** of the shaft **223** may be shaped to compliment the shape or contour of the support member **330**.

The depth and shape of the recess **340** in the housing **110** illustratively are selected to control the amount of lift desired. In illustrative embodiments, the recess **340** is spherically shaped with an inner diameter that is slightly larger than the outer diameter of the ball bearing **330**. Alternative recesses may be other shapes, such as oval or cylindrically shaped. As an example, the depth of a spherically shaped recess may be selected (based on the support member **330**) to cause the support member **330** to lift the rotor about 0.005 inches higher than it would be if the support member **330** and recess **340** were absent. Accordingly, to give a higher lift to the rotor **220**, the support member **330** is spherically shaped with a radius that is greater than the depth of the recess **340**. Alternatively, to give a smaller lift to the rotor **220**, the depth of the recess **340** can be greater than the radius of the spherical support member **330**. Accordingly, depending upon the amount of rotor lift desired, the depth of the recess **340** can range from a minimal depth to one nearly approximating the diameter of the support member **330**.

This lift illustratively lifts the rotor hub **227** so that its distance from the sleeve bearing **232** is slightly greater than the thickness of the upper thrust washer **242**. For example, the support member **330** and recess **340** may cooperate to lift the rotor **220** a distance of about 0.005 inches. In that case, if the upper thrust washer **242** has a thickness of about 0.1 inches, then the distance between the sleeve bearing **232** and the rotor hub **227** is about 0.105 inches. Consequently, the lift gives about a 0.005 inch clearance between the nominally positioned upper thrush washer **242** and the rotor hub **227**.

Those skilled in the art thus should understand that this lift changes the surface that supports the weight of the rotor **220**. Specifically, the support member **330** supports the rotor weight; the top surface **337** of the sleeve bearing **232** does not. Indeed, an internal motor component (i.e., the support member **330**) still supports the weight of the rotor **220**. That internal motor component **330**, however, has a much smaller surface area than hub **227** and receives some lubricant (discussed below). Moreover, the material choice of the support member **330** can further enhance the friction mitigation goals. For example, rather than having the plastic hub **227** rub against the metal sleeve bearing **232**, illustrative embodiments of the invention use a lubricated metal ball bearing **330** to frictionally contact the metal shaft **232**.

As noted above, the lower thrust washer **244** does not act as an efficient seal to the sleeve bearing **232**. More particularly, the thrust washers **242** and **244** are not intended to be full seals and, thus, permit some leakage over time. Consequently, lubricant may migrate from the sleeve bearing **232**, along the shaft **223**, and to the support member **330**. If the support member **330** is a metal ball bearing, then the migrating lubricant should reduce the friction caused by contact between the bottom **224** of the shaft **223** and the top of the ball bearing **330**. Moreover, to some extent, the closed base portion **320** of the housing **110** should retain the migrating lubricant within the housing **110**. Accordingly, the lubricant also should reduce the

frictional contact between the ball bearing **330** and the internal surface of the recess **340**.

To preserve proper positioning of the rotor **220** with respect to the stator **230**, the shaft lower surface **224** abuts the support member **330**. During operation, this abutment is promoted by a magnetic bias produced by the rotor magnet **260** and stator pole **360**. Specifically, the rotor magnet **260** is designed to have an axial asymmetry with stator pole **360**, thus axially biasing the rotor shaft **223** toward the support member **330**.

To those ends, the height of the rotor magnet **260** exceeds the height of the stator pole **360**. Although the magnetic field between the rotor magnet **260** and the stator pole **360** is predominantly radial in direction, where the rotor magnet **260** does not overlap the stator pole **360**, there is a component of magnetic field in the axial direction. Since the overlap (shown as "G" in figure 3) at the upper magnet end **262** exceeds the overlap (shown as "H" in figure 3) at the lower magnet end **264**, there is an axial force pulling the rotor **220** and the rotor shaft **223** toward the back cover **108**. This force thus biases the rotor **220** toward the moveable support member **330**. As a result, whether the motor **210** is right side up or upside down, the shaft lower end **224** should remain in contact with and supported by the moveable member **330**. Of course, if some condition overcomes this bias, or if the motor **210** is not operating, the retaining member **310** still maintains the axial position of the rotor **220**.

During operation, the fan motor **210** rotates the rotor about the axis **380** defined by the shaft **223**. The thrust washers **242** and **244** also rotate about the shaft axis **380** at a speed controlled by that of the shaft **223** and the amount of lubricant they receive. The thrust washers **242** and **244** therefore frictionally rub against the top **337** and bottom **338** of the sleeve bearing **232**. Moreover, to some extent, the outer surface **226** of the shaft **223** also may frictionally rub against the inner surface

**245** of the thrust washers **242** and **244**. This resistance nevertheless can be minimized by the lubricant.

When the rotor **220** rotates, the top thrust washer **242** also may move axially between the top **337** of the sleeve bearing **232** and the bottom **228** of the rotor hub **227**. This axial movement is based upon the amount of lift provided by the support member **330**. Consequently, because illustrative embodiments maintain a relatively small amount of lift, this axial movement should have a negligible impact on motor performance.

The bottom thrust washer **244** also may move axially between the retaining member **310** and the bottom of the sleeve bearing **338**. Of course, this amount of movement also is controlled by the clearance between the bottom thrust washer **244** and the retaining member **310** (when the bottom thrust washer **244** is flush against the sleeve bearing **232**). This clearance also is a function of the amount of lift provided by the support member **330**. As an example, if the clearance is about 0.005 inches, then the thrust washer **244** may have an axial freedom of movement for about 0.005 inches along the shaft **223**. Moreover, in this example, if the bottom thrust washer **244** has a thickness of about 0.01 inches, then the retaining member **330** is about 0.0105 inches from the bottom **338** of the sleeve bearing **232**.

Also during operation, lubricant drawn from pores **233** lubricates contacts points between the shaft **223** and the inner walls **339** of the sleeve bearing. In addition, lubricant also lubricates contact points between the thrust washers **242** and **244** and sleeve bearing **223** (if there is contact), and contact points between the support member **330** and the bottom **224** of the shaft **223**.

Wear of support member **330** may be reduced by the continual movement of the support member **330**. Specifically, when the shaft **223** rotates, the support member **330** rotates within the recess **340** to continually expose different regions of its surface to contact with the shaft lower end **224**. Lubricant contained within the

cavity **320** may ease the relative movement between the support member **330** and the shaft lower end **224**.

In certain situations, such as during shipment, the fan assembly **100** may be shaken to an extent that the magnetic coupling between rotor magnet **260** and stator **360** is unable to maintain contact between moveable member **330** and shaft lower end **224**. Under these circumstances, the retaining member **310** is positioned to maintain the moveable member **330** within the recess **340**. In illustrative embodiments, since the distance between the retaining member and the lower thrust washer **244** is less than the radius of the recess **340**, the retaining member **310** contacts the lower thrust washer **244** to halt axial movement of the shaft **223** prior to disengagement of the moveable member **330** from the recess **340**.

Accordingly, illustrative embodiments of the invention improve on the prior art by substantially reducing or eliminating frictional resistance produced when the rotor hub **227** contacts either the top thrust washer **242** or the sleeve bearing **232**. The support member **330** facilitates this by lifting the rotor **220** while moving within the recess **340**. Among other benefits, this reduced friction improves motor efficiency and reduces heat produced by the motor **210**. Reducing the heat can be especially important when the motor **210** is implemented as a fan in a relatively hot location.

The described embodiments of the invention are intended to be merely exemplary and numerous variations and modifications will be apparent to those skilled in the art. All such variations and modifications are intended to be within the scope of the present invention as defined in the appended claims.